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1. Title of the Invention:
Variable Directivity Antenna

2. Claim:

A variable directivity antenna comprising: first and second dipole or folded-dipole antennas disposed orthogonally in the same horizontal plane; a combiner for combining a first signal received by the first antenna and a second signal received by the second antenna; a first PIN diode interposed between the first antenna and the combiner for attenuating the first signal in accordance with a magnitude of a forward current; a second PIN diode interposed between the second antenna and the combiner for attenuating the second signal in accordance with a magnitude of a forward current; and a forward current supplying unit connected to the first and second PIN diodes, said forward current supplying unit supplying a forward current at a predetermined magnitude to the second PIN diode while said unit is supplying a forward current varying from zero to a predetermined value to the first PIN diode, and supplying a forward current at the predetermined to the first PIN diode while said unit is supplying, to the second PIN diode, a forward current varying from the predetermined value to zero.

3. Detailed Description:

This invention relates to a variable directivity antenna having variable directivity.

In order to receive broadcast waves from a plurality of stations coming from different directions, it has been done to install a plurality of antennas for different directions, to mechanically rotate a unidirectional antenna, or to use a nondirectional antenna. However, using a plurality of antennas or rotating an antenna requires complicated equipment, which leads to increase of costs. A nondirectional antenna is subject to interfering waves.

An object of this invention is to provide a variable directivity antenna which

requires simple equipment, inexpensive and is not influences by interfering waves. The antenna is realized by varying directivities of a set of antennas.

This invention is described hereinafter with reference to one embodiment shown in the accompanying drawings. A variable directivity antenna according to an embodiment includes dipole antennas 1 and 2 disposed orthogonal to each other, as shown in FIGURE 1. As shown in FIGURE 2, the dipole antenna 1 is connected to one input of a combiner 6 via a matching device 3, a PIN diode 4 and a DC blocking capacitor 5.

The dipole antenna 2 is connected to the other input of the combiner 6 via a bridge circuit 12 formed of PIN diodes 7, 8, 9 and 10 and a high-frequency blocking coil 11, and a matching device 14. Reference numerals 15, 16 and 17 denote DC blocking capacitors. The arrangement thus far described (i.e. the arrangement within a broken-line box in FIGURE 2) is mounted on a antenna post together with the dipole antennas 1 and 2.

A variable resistor 18 has its midpoint grounded, has one end connected through a resistor 19 to a positive voltage supply, has the other end connected through a resistor 20 to a negative voltage supply, and has its arm 21 connected through a high-frequency blocking coil 22 to the output of the combiner. The positive and negative voltage supplies provide voltages of the same magnitude, but of opposite polarities. The combiner 6 is coupled through a DC blocking capacitor 23 to a receiver (not shown). A variable resistor 24 has its midpoint connected through a resistor 25 to the positive voltage supply, has its opposite ends both grounded, and has its arm 26 connected through a high-frequency blocking coil 27 to the anode of the PIN diode 4. The arms 21 and 26 of the variable resistors 18 and 24 are operated together. As the arms 21 and 26 move, resistance R_{21} exhibited between the arm 21 and the ground and resistance R_{26} exhibited between the arm 26 and the ground vary in the following manner. The maximum resistance provided by the variable resistors 18 and 20 are R. When the arms 21 and 26 are at the rightmost ends, i.e. at points a in FIGURE 2, R_{21} is R/2 and R_{26} is zero. As the arms 21 and 26 are moved toward points b, R_{21} remains R/2, while R_{26} increases toward R/2, and, when the arms 21 and 26 reach the points b, both R_{21} and R_{26} become R/2. As the arms 21 and 26 move further toward point c, R_{21} decreases toward zero (0), while R_{26} remains R/2. When the arms 21 and 26 reach the points c, R_{26} becomes zero

(0) and R_{21} becomes R/2. As the arms 21 and 26 further move toward points d, R_{21} increases toward R/2, whereas R_{26} remains R/2. When the arms 21 and 26 arrive at the point d, both R_{21} and R_{26} are R/2. As the arms 21 and 26 move toward points e, R_{21} maintains to be R/2, whereas R_{26} decreases toward zero (0), and, when the arms 21 and 26 arrive at the points e, R_{21} is R/2, and R_{26} becomes zero (0). The variable resistors 18 and 24 are disposed around the receiver.

Now, operation of the variable directivity antenna is described. The dipole antenna 1 itself exhibits an 8-shaped directivity pattern 27 shown in FIGURE 3, and the dipole antenna 2 itself exhibits an 8-shaped directivity pattern 28 shown in FIGURE 3. The half-width of the directivity of each of the half-wavelength dipole antennas 1 and 2 is actually 78°, but, for simplicity of illustration, the directivity is drawn as the half-width was 90° in FIGURE 3. Let it be assumed that the maximum value of the electric field intensity on a circle having a sufficiently large radius about the center 29 of the dipole antennas 1 and 2 is unity (1), and that the angle formed between a point on the circle and the dipole antenna 2 is θ. As described in detail later, the PIN diode 4 and the bridge circuit 12 both operate as an attenuator, and their attenuation factors are k_1 and k_2, respectively, where $0 \le k_1 \le 1$, and $0 \le k_2 \le 1$. As will be understood from FIGURE 3, the directivity E (θ) is expressed as:

$$E(\theta) = k_1\cos + k_2\sin\theta$$
$$= \sqrt{k_1^2 + k_2^2}\,\sin(\vartheta + \alpha),$$

where $\alpha = \tan^{-1}(k_1/k_2)$. This directivity is expressed as an 8-shaped pattern, and, by changing the values of k_1 and k_2, the angle δ (FIGURE 4) between the direction of maximum radiation and the dipole antenna 2 can be varied.

More specifically, assuming that the arms 21 and 26 are at points a, the positive voltage is applied to the bridge circuit 12 through the arm 21, the combiner 6 and the matching device 12, so that the PIN diodes 7 and 8 are rendered fully conductive, and the attenuation factor k_1 becomes 1. The arm 26 is grounded, so that the PIN diode 4 is nonconductive, and, therefore, the attenuation factor k_2 is zero (0). Then, the variable antenna 2 exhibits an 8-shaped directivity pattern as shown in FIGURE 4(a) in which the angle δ is 90°.

When the arms 21 and 26 are moved toward the points b, k_1 remains to be unity (1) since R_{21} is R/2 as described previously, while R_{26} increases toward R/2. and the conductivity of the PIN diode 4 increases accordingly, resulting in

increase of k_2. Accordingly, the angle δ decreases. When the arms 21 and 26 reach the points b, where both R_{21} and R_{26} are R/2, the PIN diode 4 becomes fully conductive, and, therefore, k_1 and k_2 are both unity (1), resulting in the angle δ becoming 45° as shown in FIGURE 4(b).

As the arms 21 and 26 are moved toward the points c, R_{21} decreases toward zero (0), while R_{26} remains to be R/2, and, therefore, k_1 remains to be unity (1) and k_2 decreases. This results in further decrease of the angle δ. When the arms 21 and 26 reach the points c, the PIN diodes 7 and 8 become nonconductive, so that k_2 becomes zero (0) and, accordingly, the angle δ becomes 0° as shown in FIGURE 4(c).

As the arms 21 and 26 move toward the point d, while k_1 is unity (1) because the full conduction of the PIN diode 4 is maintained, the PIN diodes 9 and 10 begin to be conductive. This causes k_2 to increase again and, also, causes the phase of the dipole antenna 2 to be inverted, leading the angle δ to change to negative. When the arms 21 and 26 reach the points d, both k_1 and k_2 become unity (1), so that the angle δ becomes -45° as shown in FIGURE 4(d).

As the arms 21 and 26 move toward the points e, while k_1 decreases, k_2 remains unit (1), the angle δ changes toward -90°, and, upon arrival of the arms 21 and 26 at the points e, k_1 and k_2 become zero (0) and unit (1), respectively. This causes the angle δ to be -90° as shown in FIGURE 4(e). The operation gain of the antenna is equivalent to that of a turnstile nondirectional antenna when δ = 0° or δ = ±90°, and is larger to some extent when δ = ±45°.

Since this variable directivity antenna is arranged such that one of the signals received by the dipole antennas 1 and 2 is attenuated and combined with the signal received by the other, it can provide an 8-shaped directivity with the variable angle δ. Since the directivity can be varied electrically, the equipment is simple and inexpensive, and, in addition, the antenna is not affected by interfering waves because it can retain an 8-shaped directivity.

The antenna according to the above-described embodiment employs dipole antennas, but folded dipole antennas can be used instead. In the described embodiment, the angle δ is varied between -90° and 90°, but, if it is required that the angle δ be changed from 0° to 90°, the PIN diodes of the bridge circuit 12 can be eliminated, leaving only the PIN diode 7.

4. Brief Description of the Drawings:

FIGURE 1 shows how to arrange dipole antennas for a variable directivity antenna according to the invention; FIGURE 2 is a circuit diagram of the variable directivity antenna; FIGURE 3 shows a directivity pattern of the antenna of FIGURE 1; and FIGURE 4 is for use in explaining how the directivity of the variable directivity antenna according to the invention varies.

1 and 2: Dipole Antennas; 4: First PIN diode; 6: Combiner; 7: Second PIN Diode

17 and 24, and 19, 20 and 25: Variable Resistors and Resistors, respectively, forming Forward Current Supplying Unit